Physically-based modelling techniques for sound and synthesis

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Among the many physically-based modelling techniques, various have been designed in computer music for sound synthesis [Castagne & Cadoz 06]. The following reviews some of the most important.

Wave-guides

A 1D wave-guide is a double delay line, looped on the extremities, with losses and dispersion consolidated at the sparse points [Smith 86] [Smith 92] [Smith 96]. Such a set of filters realizes an elegant and really efficient solving of the linear propagation equation. Extensions toward 2D or 3D meshes are today possible.

Wave-guides are heavily used today for sound synthesis; most physically-based sound synthesizers implement digital waveguides, and much research is devoted to them.

The technique is modular, but its basic module, the delay-filter, can hardly be considered as a physical model in itself. The mental model it enables is meaningful, but is not very efficient when the goal is to let a musician (a end user) handle the scheme at a basic level to design its own models.

Since they model the wave propagation rather than matter in itself, wave-guides are specifically dedicated to the modelling of linear oscillating objects, and particularly sound objects. The technique, though, is not well adequate for the modelling of non-linear resonators, and does not apply to the modelling of moving objects and solids.

Modal modelling

Modal modelling (or spectral approach) proposes to model an object in the modal domain [Adrien 91].

Within the modal scheme, a vibrating structure is represented through a series of independent elementary oscillators, provided with coupling data. Each oscillator stands for a mode of the structure and is defined by its resonant frequency and damping time. The matrix coupling data encodes the modal shapes of the structure for each mode.

Modal representation is particularly adequate when dealing with linear oscillating objects, in which the oscillatory properties (i.e. the modes) are important. Hence, modal synthesis developed well in the context of computer music and sound synthesis – though a few trials have been published in computer graphics. In theses contexts, additionally, the properties of the modes are particularly relevant to manipulate, since they correspond, rapidly said, with the frequency spectrum of the sounds to be produced, which is of primary importance for human hearing [→ Auditory perception]. The scheme successfully led to software environments, such as Modalys [Morrison & Adrien 93].

Conversely, the modal technique is hardly usable for the modelling of non-linear resonators and for any object that cannot be characterized efficiently through its oscillatory properties. Additionally, the scheme is not really modular; a mode, in itself, cannot be seen as an object, so that a model necessarily corresponds with a pre-built series of modes and coupling data.

Mass-interaction framework

Mass-Interaction modelling [Cadoz et al., 93] is also being used successfully in computer music for sound synthesis, in which context it enables many benefits, including: full modularity, good usability, inherent possibility of non-linear structures, etc.

Being very generic, the mass-interaction framework is in fact adequate to model most dynamic object for generating most categories of sensory phenomena. It is hence discussed with more detail in the item [→ Physically-based modelling techniques for multisensory simulation].

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